TESTING REPORT

Title: Building Testing and Monitoring at the Habitat/SIPA/APA Project in Plains, GA
Date: 04 June 1998
Location: Plains, Georgia
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Purpose: Air tightness testing of two structural insulated panel houses and a conventional wood frame house. Installation of equipment for long-term monitoring of energy use and environmental conditions.

Executive Summary:

On 18-19 February 1998, two structural insulated panel (SIP) houses and one conventional 2x4 wood frame house were tested. The houses were all single-story, slab-on-grade, and similar in size (average 1100 ft^2). They were constructed by the Sumter County Habitat for Humanity Affiliate, with some assistance on the SIP houses from the Structural Insulated Panel Association. For the wood frame house, all construction and energy related details remained as standard practice for the Habitat Affiliate. While all three houses showed good performance for building envelope and duct system airtightness, the SIP houses showed excellent performance. The SIP houses had blower door tested airtightness of 1.8 air changes per hour at -50 Pa compared to 3.9 for the conventional wood frame house.

For each of the houses, a building audit was completed for the purpose of energy analysis for predicted peak heating and cooling load and annual energy consumption. With respect to the SIP houses, the frame house showed lower predicted annual space conditioning energy consumption but higher peak loads. The SIP houses had lower insulation values in the ceilings and walls than the frame house. However, the frame house had more window area and had its forced air ducts in the attic with a small amount of duct leakage to the outside. A home energy rating was also computed using REMRate. None of the houses met EPA/DOE Energy Star status primarily due to the uninsulated floor slab and electric resistance heat.

Monitoring equipment for energy use and environmental conditions was installed but was not yet made operational due to lack of utility power at each house. We plan to monitor the houses from June 1998 through May 1999.

Mechanical ventilation should be installed for wintertime operation, when the house is closed up, to provide adequate fresh air for the occupants. This could be accomplished using a high quality exhaust fan, meant for continuous duty, with an automatic timer and manual override. The houses currently do not have cooling systems. If it was intended to later install central, or window cooling equipment, a central-fan-integrated supply ventilation approach would be recommended *instead of* exhaust ventilation.

Discussion:

On 18-19 February 1998 Armin Rudd, Bob Abernethy, and Wayne Nelson worked together to conduct testing and monitoring installation at the Sumter County Habitat for Humanity site on Youngs Mill Road in Plains, Georgia. The overall project involved the combined efforts from Habitat for Humanity, the Structural Insulated Panel Association (SIPA), APA – The Engineered Wood Association, and the U.S. Department of Energy including subcontractors.

Building Airtightness Testing

Two structural insulated panel (SIP) houses and one conventional 2x4 wood frame house were tested by fan depressurization for airtightness of the building envelope and forced air distribution system (ducts). The houses were all single-story, slab-on-grade, and similar in size (average 1100 ft^2). They were constructed by the Sumter County Habitat for Humanity Affiliate, with some assistance on the SIP houses from the Structural Insulated Panel Association. For the wood frame house, all construction and energy related details remained as standard practice for the Habitat Affiliate.

Building envelope air leakage was measured by means of a Minneapolis Blower Door with digital pressure gauges. Table 1 lists the airtightness testing results and gives a short description of the construction. All of the houses tested had low building air leakage rates, which is good. Even so, the average building air leakage (EEBA Criteria) of the two SIP houses was still 31% lower than the building leakage of the standard wood frame house with the whole house fan sealed off.

Mechanical ventilation, other than standard bathroom exhaust, was not a design consideration, but it should be. Mechanical ventilation should be installed for wintertime operation, when the house is closed up, to provide adequate fresh air for the occupants. This could be accomplished using a high quality exhaust fan, meant for continuous duty, with an automatic timer and manual override. The fan could be installed as an upgrade to the existing bathroom fan, as long as the bathroom door was left at least partially open when the bathroom was not in use, or if other means were provided to allow air to flow from the central part of the house to the bathroom. The houses currently do not have cooling systems. If it was intended to later install central, or window cooling equipment, a central-fan-integrated supply ventilation approach would be recommended *instead of* exhaust ventilation. The central-fan-integrated supply ventilation approach involves a fresh air duct, routed from an exterior gable or soffit location to the central system fan return, and a specialized recycling control that functions to operate the fan for a selected ON time if it hasn't already operated for a selected OFF time. This ventilation approach can be installed for $125, and will also improve occupant comfort by making temperature and humidity conditions more uniform throughout the house.

The wood frame house has a large attic fan mounted in the ceiling of the hallway. Since none of the Habitat houses in this area have cooling systems installed, the intent of this fan was improve comfort conditions during warm weather. The fan louvers are passively operated by pressure induced by the fan when it is operating. The louvers have no weather stripping and contribute a large part to the building envelope leakage. This was measured by taping off the attic fan. The house leakage rate at -50 Pa dropped 226 cfm (26%) with the attic fan taped off. It is recommended that the attic fan be sealed off when not in use, especially in cold weather.

Using a smoke pencil with the house pressurized to 20 Pa, it was found that leakage through electrical boxes on outside walls was minimal. Penetrations through the wall top plates were sealed during construction. On the wood frame house, the foam exterior sheathing joints were taped, and the foam also tends to compress to the wall framing. Wall sill plates were caulked to the slab floor. The double-glazed, vinyl-frame, single-hung windows also showed low leakage.

Table 1

Building Airtightness Testing by Fan Depressurization						
Habitat/SIPA/APA Project in Plains, GA						
	EEBA	**ELA**	**CFM50**	**ACH50**	**Estimated**	
Unit	(cfm/ft^2)	(in^2)				
SIP houses						
880 Youngs Mill	0.11	19	390	1.8	0.07	SIP walls and ceiling, slab
884 Youngs Mill	0.14	31	475	1.8	0.07	SIP walls and ceiling, slab
Wood-frame house						
894 Youngs Mill	0.24	47	881	5.3 (3.9)*	0.20 (0.15)*	2x4 16" O.C. frame wall,

* Whole house fan sealed off
where: EEBA Criteria = Energy Efficient Building Association Criteria of less than 0.25 cfm of leakage per square foot of building surface area (including floor)
ELA = effective leak area (in^2) calculated at a 4 Pa pressure differential
CFM50 = cubic feet per minute of air leakage at a 50 Pa pressure differential
ACH50 = air changes per hour at 50 Pa pressure differential
Estimated natural ACH = estimated natural air changes per hour under annual average conditions

Measurement of natural air change rate under prevailing conditions was made by tracer gas decay. This testing was conducted in the eastern-most SIP house, then in the wood frame house. Table 2 lists the results. Both houses exhibited low air change rates even under breezy to windy conditions. However, since the houses were not heated, there was little stack effect due to indoor to outdoor temperature differential.

Table 2

894 Youngs Mill	0.16	breezy to windy, T_{out}=58 F, T_{in}=63 F

Forced Air Distribution System Airtightness Testing

Duct system airtightness testing was conducted for each of the three houses using fan depressurization. Air flow was measured through an Energy Conservatory DuctBlaster®. Table 3 summarizes the results. All three houses had low, or no duct leakage to outdoors, which is excellent. A duct leakage criteria proposed by the Florida Solar Energy Center requires that duct leakage to outdoors be less than 3% of the conditioned floor area. All of the houses meet that criteria. For the SIP houses, all of the ducts are inside conditioned space. While for the wood frame house, the ducts are located in the attic, making the low duct leakage rate especially important.

Observations of the duct system were as follows:

1. Air handler unit (AHU) located inside interior utility closet on platform
2. Central return below AHU platform
3. Metal supply trunk leaving AHU, with mastic on joints
4. 6" flexible duct supply takeoffs from the metal supply trunk

   – inside duct liner tie-wrapped
   – duct insulation wrap taped or sealed with mastic
   – R-6 duct insulation

1. Supply boots caulked to the ceiling drywall

Table 3

Duct Airtightness Testing					
Habitat/SIPA/APA Project in Plains, GA					
	Floor Area (ft^2)	**Total Leakage (cfm @ 25 Pa)**	**Percent of Floor Area**	**Leakage to Outside (cfm @ 25 Pa)**	**Percent of Floor Area**
SIP houses					
880 Youngs Mill	1036	128	12.4	0	2.0
884 Youngs Mill	1069	115	10.8	0	2.3

Wood-frame house					
894 Youngs Mill	1208	121	10.0	31	2.6

For each of the houses, a building audit was completed for the purpose of energy analysis for predicted peak heating and cooling load and annual energy consumption. This information is given in Table 4. With respect to the SIP houses, the frame house showed lower annual space conditioning energy consumption but higher peak loads. The SIP houses had lower insulation values in the ceilings and walls than the frame house. However, the frame house had more window area and had its forced air ducts in the attic with a small amount of duct leakage to the outside.

Table 4

Predicted Energy Consumption and Peak Loads						
	Annual Energy Consumption				Peak Loads	
	Heating kWh	Cooling kWh	Total kWh	Total kWh/sqft	Cooling kW	Heating kW
880, SIP, Plan 3d19	2959	1904	4864	4.69	3.1	4.0
884, SIP, Plan 3d22	2989	1817	4805	4.50	3.0	3.9
894, Wood frame, Plan 4d46	2549	2139	4688	3.88	4.0	4.5

A home energy rating was also computed using REMRate created by Architectural Energy Corporation in Boulder, Colorado, which is intended to follow the guidelines published by the Home Energy Rating Systems Council in Washington, D.C. The reference house always scores an 80. The EPA/DOE Energy Star program labels a house as Energy Star compliant if the rated house scores 86 or above. The rated house has the equivalent of five percent better energy performance than the reference house for every point above 80 and five percent lower energy performance for every point below 80. As shown in Table 5 the ratings for all of the houses was 83. None of the houses made Energy Star status primarily due to the use of electric resistance heat and the uninsulated concrete slab floor.

Table 5

Home Energy Rating			
	Conditioned Floor Area (ft^2)	HERS Score	% Better Than HERS Reference House
SIP houses			
880 Youngs Mill, Plan 3d19	1036	82.7	13.5%

884 Youngs Mill, Plan 3d22	1069	83.0	15.0%
Wood-frame house			
894 Youngs Mill, Plan 4d46	1208	82.9	14.5%

Monitoring

Sensors and dataloggers were installed in all three houses for long-term monitoring of energy use and indoor environmental conditions. Measurement points for the all-electric houses are:

1. whole house electrical energy use
2. electric resistance forced air furnace energy use
3. electric resistance domestic hot water energy use
4. indoor temperature (two locations)
5. indoor relative humidity

The houses are side-by-side and a weather station was installed on a southern exposure of the center SIP house. Outdoor environment measurement points are:

1. outside temperature
2. outside relative humidity
3. global horizontal solar radiation

The houses did not have electrical power at the time of monitoring equipment installation. Therefore, the sensors and dataloggers were installed but not yet made operational. We plan to monitor the houses from June 1998 through May 1999.
